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THE GROWTH OF BOYS: CORRELATIONS FOR THE ANNUAL INCREMENTS

By CLARK WISSLER

The real problem in studies of growth is the determination of the annual increments during the period of growth for each degree of adult stature. Until we have sufficient measurements to tell us how the tall men and likewise the short men grew in boyhood, we can form no idea of the significance of any given part of the growing period. Thus far our knowledge of growth, as determined by physical measurements of children, is based on average statures obtained by single measurements of large groups of children. We thus gain a certain general curve of growth from which we infer certain tendencies to periodic growth. In all such measurements we have ample means for determining the variation between individuals at each period of life, but no way of estimating the degree of variation in the same individual from year to year. Thus, while we know that the average maximum increase in the stature of boys occurs about the fourteenth year of life, we have no means of knowing how many boys reach their maximum before or after this point. Further, we have no data from which to infer the influence of rapid growth in one year of life on the rate of growth in later years and on the final adult stature. It is generally assumed that the curve of growth obtained from mass measurements is typical of individual growth and that the individual curves will be the same whether the pubertial maximum period of growth comes before or after the fourteenth year. A few life-records of individual children published from time to time suggest the invalidity of this assumption, but aside from these few isolated cases there are no data to which appeal can be made. In consequence, any series of annual measurements of a considerable number of children during the period of pubertial changes must be an important contribution to our knowledge. Recently there came into my hands the gymnasium records[1] of a private school for boys from which the annual increments for the various physical measurements could be determined. Boys attended this school between the ages of eleven and eighteen, some being regular attendants for eight consecutive years, a few for a period of nine to ten years, while the majority were in attendance from four to five consecutive years between the eleventh and seventeenth years of life. There were in all about 300 individuals, making something more than 1500 annual measurements. While this is a fair number of cases, irregularities in age of entrance and of leaving school reduce the number of cases to such a degree that the comparison of annual increments for three-, four-, and five-year intervals becomes difficult. In other words, the number of boys presenting an unbroken series of annual measurements for periods of six years or more is relatively small — too small, in fact, to lead to safe conclusions unless extremely uniform results are obtained. Yet this is precisely the way the results turn out.

Although a considerable number of gymnasium measurements were taken — stature, weight, arm-reach, height sitting, length of sternum, etc., the following results are for stature and weight only. The reason for such selection is rather obvious, since they are the two general indices of growth. Stature was recorded in centimeters, reading to the nearest unit, and weight in kilograms, reading to tenths. The latter is sufficiently exact for the purpose; but it would have been more precise to have taken stature in millimeters, since the annual increment may often be less than a centimeter. Ages were counted to the nearest birthday. This rounding off of stature and ages makes the comparison of annual increments somewhat uncertain because arbitrary, but the usual method of recording gymnasium measurements makes it impossible to do otherwise.

As stated at the outset, the interesting problem is the correlation of increments; but it seems desirable to mention some preliminary data before proceeding. For these measurements the maximum rate of annual increase for stature, arm-reach, and weight is found between the ages of 14 and 15, but the decrease for later years is less in case of weight than the other measurements.

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[1] These were secured through the kindness of Dr Franz Boas and the calculations were made at his suggestion. The writer is so greatly indebted to him for suggestions and criticisms that he is unable to designate his own particular contribution to the research. It is, however, fair to say that the writer is alone responsible for all computations and interpretations herein reported.

Another preliminary point is the degree of correlation between the annual increments for the different measurements. Calculating the correlation by the Pearson formula, we have the following:[1]

Age interval	12–13	13–14	14–15	15–16
Increment for stature and weight	+ 0.70	+ 0.75	+ 0.50	+ 0.60
Increment for stature and arm-reach	+ 0.72	+ 0.92	+ 0.73	+ 0.95

From this it appears that there is a close correlation between the rates of growth for these bodily dimensions, and that with respect to them the body grows with considerable uniformity and by parts regularly.

We are now ready to inquire as to the correlation of annual increments and will state the results at once. If we correlate the absolute stature with the absolute increment for the following year, the weight with its increment, and likewise the arm-reach, the following coëfficients of correlation are obtained:

Ages	12	13	14	15
Stature and increment	+ 0.41	+ 0.30	— 0.30	— 0.51
Weight " "	+ 0.35	+ 0.35	+ 0.11	— 0.27
Arm-reach and "		+ 0.36	— 0.33	— 0.32

The number of cases for each correlation varies from 126 to 199.

The important point in this table is the change of sign of the coëfficient of correlation between the years of 13 and 14. The change is quite abrupt in stature and arm-reach. While the sign of the coëfficient for weight in the fourteenth year is positive, the coëfficient itself is very small. The probable interpretation of this is that the change of sign occurs half a year later than in the case of stature. The simpler statement of this technical fact would be that, in case of stature, the boys who were tall at 12 years grow the faster during the interval 12–13 and 13–14; but during the intervals of 14–15 and 15–16 they grow slowly; with the boys of short stature at 12 the rates of growth are exactly the reverse. This means that there is a marked tendency for boys growing rapidly at 12 to continue to the year of the pubertial maximum, while those growing slowly at 12 continue on about the same level until near that point, when they in turn begin to grow rapidly. What is true of stature is likewise true of other measurements.

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[1] The general method of correlation need not be explained here. It is necessary only to know that the degree of correlation is expressed in a scale of + 1.00 to — 1.00. The former signifies a perfect direct correlation, the latter a perfect inverse correlation, and the intermediate zero no correlation whatever. The degree of correlation in the above can be read into this scale according to the decimal.

While the above is in some respects a correlation between size and annual increment, the same compensating relation holds for the successive annual increments. It also appears that the annual increments afford greater opportunity for correlation than the increments and size, since we can readily correlate across large and small age intervals. This may be seen from what follows.

The data at hand furnished records of seventy boys, complete between the ages of 12 and 17. With these the correlations between all the annual increments have been calculated for stature and weight.

CORRELATION OF THE ANNUAL INCREMENTS OF STATURE

Ages.	12–13	13–14	14–15	15–16	16–17
12–13	+1.00	+0.45	−0.02	−0.62	−0.70
13–14	+0.45	+1.00	−0.04	−0.56	−0.66
14–15	−0.02	−0.04	+1.00	+0.43	−0.03
15–16	−0.62	−0.56	+0.43	+1.00	+0.61
16–17	−0.70	−0.66	−0.03	+0.61	+1.00

CORRELATION OF THE ANNUAL INCREMENTS OF WEIGHT

Ages.	12–13	13–14	14–15	15–16	16–17
12–13	+1.00	+0.39	−0.05	−0.43	−0.41
13–14	+0.39	+1.00	+0.09	−0.36	−0.31
14–15	−0.05	+0.09	+1.00	+0.03	+0.01
15–16	−0.43	−0.36	+0.03	+1.00	+0.33
16–17	−0.41	−0.31	+0.01	+0.33	+1.00

The average increments for the various intervals and their respective variabilities may be seen from the following table:

AVERAGE INCREMENTS AND VARIABILITIES

Age Interval.	Cases.	Av. Increment of Stature; *mm.*	Variability; *mm.*	Av. Increment of Weight; *kg.*	Variability; *kg.*
11–12	123	48	16	3.4	2.0
12–13	163	56	21	4.0	2.5
13–14	198	64	23	5.2	2.2
14–15	176	69	26	5.9	2.2
15–16	134	53	28	5.4	2.9
16–17	76	32	20	4.3	2.0
17–18	33	23	23	3.2	1.7

In reading the table it must be understood that 1.00 is the correlation of the increment with itself or identity. In case of the increment of stature for 12–13, for example, its correlation with itself falls in the first column, its correlation with the increment for the year 13–14 in the second column, etc. This row of coëfficients gives us a picture, or curve of growth, applicable to boys of 12–13. Whatever the relative increment for that year, we can be reasonably certain that it will persist unchanged during 13–14, that a marked change will occur in 14–15, and that the subsequent years will be marked by an inverse relative increment. The relation is plain when the table for weight is reduced to graphic form as in figure 3.

In the curves for weight the crossing point falls on the zero line in the 14–15 year and the whole curve for the annual increment 14–15 is approximately in the zero line. The same is practically true of stature. The meaning of this is that, given the annual increment of a boy for the year 14–15, absolutely nothing can be inferred as to his past or future rate of growth. The increment for that year is apparently functionally independent of all other increments, bearing only a chance relation to them. That such must be the case is evident from the mere fact that the sign of correlation changes; there must be a point somewhere where there is no correlation whatsoever. To see just what this means in case of a growing boy is not clear. It is probable that the result is due to a compensation, in that those who have been growing rapidly will now slow down irregularly, and likewise those who were growing slowly will begin to spurt at irregular intervals. The result of such a condition would be that just as many boys of a given increment at 13–14 would grow fast in 14–15 as slow, and the reverse, which is equivalent to a chance relation. Yet the maximum rate of growth occurs somewhere between 13–14 and 14–15—the "spurt," as it is often called. This spurt may come from causes independent of the conditions that determine the compensation of rates of growth before and after puberty. There seems good reason for such an assumption. If this is correct, the utter lack of correlation for 14–15 is accounted for very satisfactorily. The boys who grew slowly before that time lived under conditions less favorable to growth and the pubertial spurt met with less resistance in them. However, it is well-nigh useless to speculate in this manner because the absolute stature is a complex resultant

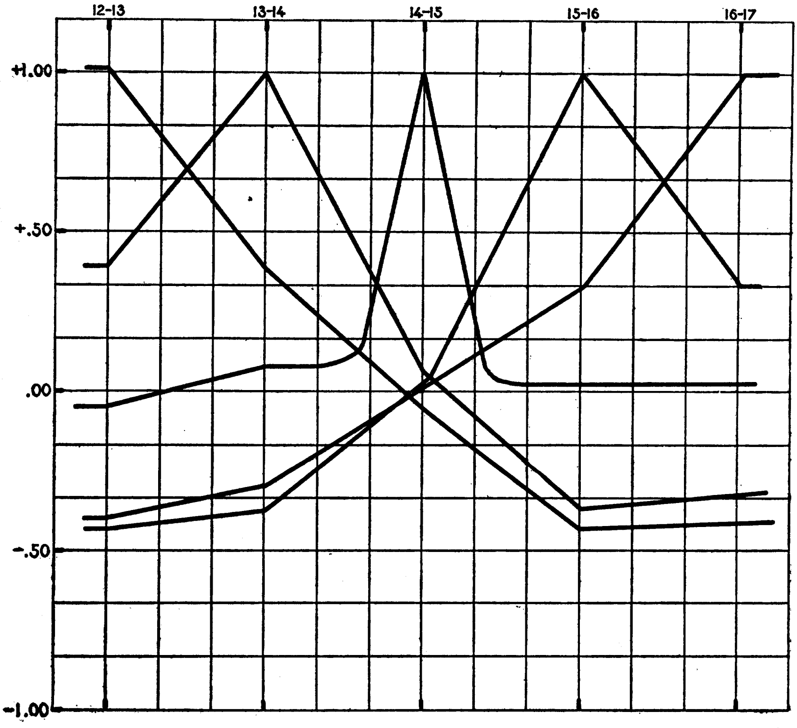

FIG. 3.—Curves showing the relative degrees of correlation for increments of weight.

of heredity, environment, accident, etc. The important fact is that there is a compensatory relation of growth between the pre-pubertial and the post-pubertial rates of growth and that the period of the pubertial maximum is a time of readjustment with respect to annual increments.

The reader may wish to know the result if intervals of more than one year are correlated. If, for example, the increment 12–13 were correlated with 13–16, what would be the coëfficient? Calculation is unnecessary, for the curves show what it must be. The correlations for the annual increments for this period are: + 0.45, — 0.02, — 0.62. The summation of these is slightly negative, which must be the approximate correlation for the whole interval. The tables are thus a complete exposition of all the possible correlations, and so tell the whole story. It is unfortunate that these measurements do not cover the period of 10–12. There were about 30 boys of 11 years from which it is possible to gain some idea of the interval 11–12. In case of 11–12 and 12–16 the indications are for a low degree of correlation. This is consistent, for we have just found that 12–13 and 13–16 are negative. In case of 11–12 and 12–16 we are choosing an increment for a symmetrical interval in relation to the period of change of sign, or the pubertial maximum. Here the compensation in growing rates would tend to no correlation. But the correlation 12–13 and 13–16 gives an interval unequally adjusted to the pubertial maximum. Thus it appears that if we correlate the increment for any interval with the increment for an interval of equal extent on either side of the pubertial maximum, no correlation will appear.

We have now reached another point. It must follow from all that has gone before that there is no correlation between the absolute stature at 12 and the absolute increment for 12–16. For 68 cases a coëfficient of — 0.06 was obtained. This again could have been answered from the tables, for the change of sign must mean that the tall boys at 12 grow slowly after 14, and the reverse, and the compensation should equalize the result. In other words, the average increment of stature for 12–16 is the same for tall as for short boys. But there is still another important point. The tall boys at 12 are also the tall boys at 16. The correlations as calculated for the absolute statures are, 12–14, + 0.94; 12–16, + 0.97. This may signify one of two relations: the short boys before 14 get their final stature much later in life, or short men are those who were short at 12 and grew slowly before 14.

For light on this point I took the seven tallest boys at 17 and the seven shortest. These were then traced back and the median increments found for the different years. In like manner the fifteen tallest and shortest at 12 years. The results show that tall boys at either end of the series are those who grew most rapidly before 14. Nor will reducing all individual increments to percentages of statures modify the result, which is the same absolutely or relatively. Other examples of this relation may be observed in the life-records of stature so far available.[1] It is of course probable that the short boys at 17 may still grow enough to overtake the others.

With respect to the whole paper a general objection may be made. It may be said that these boys are artificially selected by the school and that in consequence the relations are not true for boys in general. There is reason to believe that selection may be a factor here. For example, when we trace the 12-year-old boys through the records, it appears that of the fifteen tallest boys of that age all are in school at 16, while among the 17-year-olds only four of them are enrolled; of the fifteen shortest boys nine are in school at 17 and five at 18, none of the taller group remaining after the age of 17. From this it appears that the older boys of the school are inclined to be short in stature. But this condition does not make its appearance until the fifteenth year, and it will be remembered that the compensating rates of correlation were found between the ages of 12 and 16. This factor is then a probable intensifier of the result, but not the cause.

The general significance of the preceding results emanates from their relation to the problem of relative maturity. It appears that the tall boys at 12 are relatively more mature and that they continue so until near manhood. No doubt this relative physical maturity has given rise to false theories concerning the functional relation of mental and physical development. The results, at least, show the importance of procuring a complete series of measurements extending to full maturity.

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[1] *Jahrb. f. Kinderheilkunde*, 1893.